FORM PTO-1082

STERNE, KESSLER, GOLDSTEIN & FOX P.L.L.C.
1100 New York Avenue, N.W., Suite 600
Washington, D.C. 20005-3934

Attorney Docket No. 15-4-499.00

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Sir:

Transmitted herewith for filing is the patent application of
Inventor: Shinya Matsuoka
For: **Spatialized Audio in a Three-Dimensional, Computer-Based Scene**

Enclosed are:

xx 18 sheets of informal drawings.
___ An assignment of the invention to Silicon Graphics, Inc.
___ Form PTO-1595.
___ A certified copy of a ______________________ application.
___ An associate power of attorney.
___ A verified statement to establish small entity status under 37 CFR 1.9 and 37 CFR 1.27.
___ Executed Power of Attorney from Assignee
xx Executed Declaration for Patent Application.

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Respectfully submitted,

MBRay

Michael B. Ray
Registration No. 33,997

4/30/97
(Date)

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Rev. 4/3/97mac

STERNE, KESSLER, GOLDSTEIN & FOX P.L.L.C.
ATTORNEYS AT LAW
SUITE 600
1100 NEW YORK AVENUE, N W
WASHINGTON, D.C. 20005-3934

(202) 371-2600
FACSIMILE (202) 371-2540

WRITER'S DIRECT NUMBER:

(202) 371-2569
INTERNET ADDRESS:

mray@skgf.com

April 30, 1997

Box Patent Application

Assistant Commissioner for Patents
Washington, D.C. 20231

Re: U.S. Utility Patent Application
Appl. No.: (to be assigned); Filed: (Herewith)
For: **Spatialized Audio in a Three-Dimensional, Computer-Based Scene**
Inventors: Shinya Matsuoka
Our Ref: 15-4-499.00

Sir:

The following documents are forwarded herewith for appropriate action by the U.S. Patent and Trademark Office:

1. U.S. Utility Patent Application entitled:

Spatialized Audio in a Three-Dimensional, Computer-Based Scene

and naming as inventor:

Shinya Matsuoka

the application comprising:

a. A specification containing:

(i) 27 pages of description prior to the claims;

(ii) 9 pages of claims (25 claims, 3 independent); and

(iii) a one (1) page abstract;

b. 18 sheets of drawings: (Figures 1-4, 5A, 5B, 6-8, 9A, 9B, 10-16);

c. A copy of an original executed combined Declaration and Power of Attorney;

2. Form PTO-1082;

3. Three (3) return post cards; and

4. Our Check No. 19126 for $880.00 to cover:
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It is respectfully requested that, of the three attached post cards, one be stamped with the filing date of these documents and returned to our courier, and the other, prepaid postcards, be stamped with the filing date and unofficial application number and returned as soon as possible.

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Respectfully submitted,

STERNE, KESSLER, GOLDSTEIN & FOX P.L.L.C.

Michael B. Ray
Attorney for Applicant
Registration No. 33,997

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Enclosures

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A

Spatialized Audio in a Three-Dimensional, Computer-Based Scene

Inventor: Shinya Matsuoka

Background of the Invention

Field of the Invention

The present invention relates generally to audio conferencing, and more particularly to spatial audio in a computer-based scene.

Related Art

An audio conference consists of an environment shared by viewers using the same application over an interactive TV network. In a typical application, viewers move graphic representations (sometimes referred to as personas or avatars) on the screen interactively using a remote control or game pad. Viewers use their set-top microphones and TV speakers to talk and listen to other viewers and to hear sounds that are intended to appear to come from specific locations on the screen.

Conferencing software that supports real-time voice communications over a network is becoming very common in today's society. A distinguishing feature between different conferencing software programs is an ability to support spatialized audio, i.e., the ability to hear sounds relative to the location of the listener -- the same way one does in the real world. Many non-spatialized audio conferencing software products, such as NetMeeting, manufactured by Microsoft Corp., Redmond, WA. and Intel Corp., North Bend, WA.; CoolTalk, manufactured by Netscape Communications Corp., Mountain View, CA.; and TeleVox, manufactured by Voxware Inc., Princeton, N.J., are rigid. They do not provide distance-based attenuation (i.e., sounds are not heard relative to the distance between persona locations on the TV

screen during the conference). Non-spatialized audio conferencing software does not address certain issues necessary for performing communications in computer scenery. Such issues include: (1) efficient means for joining and leaving a conference; and (2) provision for distance attenuation and other mechanisms to provide the illusion of sounds in real space.

Spatialized audio conference software does exist. An example is Traveler, manufactured by OnLive! Technologies, Cupertino, CA., but such software packages exist mainly to navigate 3D space. Although they attempt to spatialize the audio with reference to human representatives in the scene, a sound's real world behavior is not achieved.

As users navigate through a computer-based scene such as a Virtual Reality Modeling Language (VRML) "world", they should be able to hear (and to broadcast to other users) audio sounds emanating from sources within the scene. Current systems typically do not do a very good job of realistically modeling sounds. As a result, the sounds not are heard relative to the user's current location as in the real world.

What is needed is a system and method for providing audio conferencing that provides realistic sounds that appear to emanate from positions in the scene relative to the location of the user's avatar on the TV screen.

Summary of the Invention

Briefly stated, the present invention is directed to a system and method for enabling an audio conference server (ACS) to provide an application program with multi-point, weight controllable audio conferencing functions. The present invention achieves realistic sound by providing distance-based attenuation. The present invention associates an energy level with the sound

(e.g., weak, medium, strong, etc.) to define the sound within the scene according to the sound's real world behavior.

The ACS manages a plurality of audio conferences, receives audio data from a plurality of audio clients, mixes the audio data to provide distance-based attenuation and decay characteristics of sounds, and delivers the mixed audio data to a plurality of audio clients. Audio clients include set-top box audio clients and point source audio (PSA) audio clients. Set-top box audio clients can be set-top boxes, computer workstations, and/or personal computers (PCs). PSA audio clients include audio files and audio input lines.

The ACS mixes the audio data by identifying a decay factor. Pre-defined decay factors include an audio big decay factor, an audio small decay factor, an audio medium decay factor, and a constant decay factor. One can also develop a customized decay factor. A weighted value for a source audio client based on the identified decay factor and the distance between the source audio client and a target audio client is determined. A mix table is generated using the weighted values for each source/target audio client pair. Then, an actual mix value for each target audio client is calculated using the weighted values from the mix table. The present invention also includes means for refining the actual mix value.

The ACS manages the audio conferences using an ACS shell. The ACS shell is a user interface that provides interactive program access to the ACS using high level methods for creating and managing a proxy audio conference and for creating and managing point source audios. The ACS shell also provides program access to the ACS via low level methods for creating and managing audio conferences.

The ACS also checks the status of a registered owner of each audio conference using a resource audit service (RAS). The RAS informs the ACS

when the registered conference owner stops running. Then, the ACS closes the conference.

Further features and advantages of the invention, as well as the structure and operation of various embodiments of the invention, are described in detail below with reference to the accompanying drawings. In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements. The drawing in which an element first appears is indicated by the digit(s) to the left of the two rightmost digits in the corresponding reference number.

Brief Description of the Figures

The present invention will be described with reference to the accompanying drawings, wherein:

FIG. 1 is a block diagram of an audio conferencing network environment according to a preferred embodiment of the present invention;

FIG. 2 is a block diagram of a computer system useful for implementing the present invention;

FIG. 3 is a diagram representing the threads involved in audio conferencing for the present invention;

FIG. 4 is an exemplar process of an audio conference service's conference owner thread;

FIGS. 5A and 5B represent a flow diagram of the process of changing a registered owner of an audio conference;

FIG. 6 represents a diagram representing the play back of a PSA;

FIG. 7 represents a graph showing pre-defined decay factors for four categories of sounds;

FIG. 8 is an exemplary mix table with audio mix equations for target audio clients;

FIG. 9A is a flow diagram representing the functionality of the mixer thread;

FIG. 9B is a flow diagram representing the audio mixing process;

FIG. 10 is a diagram representing program access and internal interfaces to the audio conference classes of the ACS shell;

FIG. 11 is a list of the methods contained in an ACProxy class;

FIG. 12 is a list of the methods contained in a PointSourceAudio class;

FIG. 13 is a list of the methods contained in an AudioConferenceService class;

FIG. 14 is a list of the methods contained in an AudioConference class;

FIG. 15 is a flow diagram representing the addition of an audio client to a proxy audio conference; and

FIG. 16 is an exemplary flow diagram representing an audio conference in a service application using the lower level methods of the AudioConference and AudioConferenceService classes.

Detailed Description of the Preferred Embodiments

The preferred embodiment of the present invention is discussed in detail below. While specific configurations are discussed, it should be understood that this is done for illustration purposes only. A person skilled in the relevant art will recognize that other components and configurations may be used without departing from the spirit and scope of the invention.

Overview of the Invention

The present invention is directed to a system and method for enabling an audio conference server (ACS) to provide multi-point, weight controllable audio conferencing functions to application programs. The present invention allows

application programs to incorporate audio conference features without being concerned with the details of audio processing, audio delivery, and audio data mixing. The present invention allows multiple applications to share one conference. Applications can also use a conference created by another application. The present invention allows viewers in an audio conference to hear sounds and talk to other viewers across an interactive TV network.

In an application service that incorporate the ACS, the ACS enables the application service to have audio clients. Audio clients are displayed as points on a TV screen from which sound appears to emanate. Approaching a source of sound makes the sound grow louder. Moving away from the source of sound makes the sound grow fainter. Audio clients can be point sources of sound, referred to as point source audios (PSAs), from audio files or an audio input line. Viewers having conversations with others on a network using a set-top box (STB) microphone and TV speaker are another type of audio client, often referred to as a set-top box (STB) audio client. The STB audio client includes a set-top application for controlling an audio stream of data emanating from the STB microphone or the TV speaker.

The set-top application, application service, and the ACS typically reside on separate systems, thus requiring a network communications' set-up among them. The ACS manages the data exchange and audio mixing among clients and servers. The ACS uses a COBRA (Common Object Request Broker Architecture) Interface Definition Language (IDL) interface for setting up an audio conference, and a User Datagram Protocol/Internet Protocol (UDP/IP) interface for transmitting and receiving audio streams of data. Both COBRA IDL and UDP/IP interfaces are well known to persons skilled in the relevant art(s).

The ACS receives audio streams of data from STB and PSA audio clients, mixes the audio streams of data to enable distance-based attenuation of sounds as well as decay characteristics according to the sound's behavior, and delivers

the mixed audio streams to the designated STB audio clients. Audio mixing adjusts the volume of a persona's voice (from a STB) or sound emanating from a PSA relative to the distance between the location of the sound and the audio client's persona on the TV screen: the greater the distance, the fainter the audio. Also, if the sound is a low-energy sound, such as a wind chime, the sound will decay quickly. If the sound is a high energy sound, such as a waterfall, the sound will decay slowly.

A user can interactively interface with the ACS using an ACS shell. The ACS shell, written in TCL (a tool command language developed by John Ousterhout of the University of California, Berkeley), is an IDL-based client that connects to the ACS. The ACS shell enables developers to prototype applications, and operators to monitor and control audio conferences.

Figure 1 is a block diagram of an exemplary audio conferencing network environment **100** in which the present invention is implemented. The audio conferencing network **100** includes a headend server **102** and a plurality of workstations **120**. The workstations **120** are connected to the headend server **102** via a communication bus (not explicitly shown). A typical communication bus architecture includes any one of coaxial, fiber-optic, and 10BaseT cabling, all of which are well known to persons skilled in the relevant art(s).

The headend server **102** houses an audio conference server (ACS) **104**, an application service **106**, and an ACS shell **110**. The headend server **102** may also contain PSAs **108**. The application service **106** is an application that incorporates the ACS **104**. PSAs **108** can be audio files or analog input lines. The ACS **104** enables the application service **106** to incorporate audio conference features without being concerned with the details of audio processing, audio delivery, and audio data mixing. The ACS shell **110** is an IDL client that connects to the ACS **104** to provide a user interactive interface to monitor and control the full range of ACS functions.

Each workstation **120** contains a set-top box (STB) **112** and a TV **122**. The TV **122** includes a TV screen **125** and a speaker **126**. The TV screen **125** displays the audio clients (PSAs **108** and/or STBs **112**) that are included in the audio conference while the sounds emanating from the displayed audio clients (PSAs **108** and/or STBs **112**) are heard by a viewer **124** via the TV speaker **126**. The STB **112** contains a set-top application **114**, an ACS client library **116**, and a microphone **118**. The ACS client library **116** contains application program interfaces (APIs) that are exported to the set-top application **114**. The APIs enable the set-top application **114** to control an audio stream of data emanating from the microphone **118** or the TV speaker **126**. An ACAudioClient class contains the API interface between the set-top application **114** and the ACS client library **116**. The ACAudioClient class contains methods that enable set-top applications **114** to join or leave an audio conference, start and stop audio conferencing ability for STB **112** audio clients, and to control and monitor audio talking.

The ACS **104** enables the application server **106** to have audio clients. The functionality of the ACS **104** is two-fold. First, the ACS **104** manages the audio stream of data. For example, audio sounds emanating from each STB **112** are interfaced to the ACS **104** over the communication bus using a UDP/IP interface **128**. When a viewer **124** speaks into the microphone **118**, the viewer's voice is imported from the microphone **118** to the set-top box **112** in a digitized pulse code modulation (PCM) format. PCM is a digital transmission technique by which a continuous signal is periodically sampled, quantized, and transmitted in digital binary code. PCM is well known to persons skilled in the relevant art(s). (Note that when a viewer is not speaking, silence suppression is provided to avoid flooding the network.) The ACS client library **116** sends the PCM audio data stream as UDP/IP data packets **128** over the communication bus to the ACS **104** in the headend server **102**. UDP/IP

protocol is used for real-time audio data delivery. The ACS **104** mixes the audio data stream accordingly, and sends the mixed audio data stream to each designated viewer's set-top TV speaker **126** via UDP/IP over the communication bus through the appropriate STBs **112**. Each designated viewer hears the sound relative to that viewer's position to the sound on the TV screen **125** according to the real life characteristics of the sound. If the set-top application **114** has turned on the local echo feature, the viewer's voice is also sent locally to the viewer's set-top speaker **126**. The echo is in real time; there is no network delay.

Second, the ACS **104** manages the audio conference. Conference management is performed using IDL. The application service **106** communicates with the ACS **104** over the communication bus using an IDL interface **130**. The set-top application **114** communicates with the application service **106** over the communication bus using an IDL interface **131**. Communications from the set-top application **114** that are relevant to audio conference management are translated by the application service **106** into a conference management command and passed to the ACS **104** via IDL interface **130**. The ACS **104** handles IDL requests from the application service **106**. The IDL interface **130** comprises software methods that when executed, perform various ACS functions. These methods, when called by the application service **106** are executed transparently. The methods perform such functions as creating and deleting a conference, adding and removing participants to and from the conference, respectively, changing the volume mix balance between participants in the conference, etc. Although IDL is relatively slow, IDL was chosen for its reliability.

Implementation of the Invention

The headend server **102** is preferably implemented using a computer system, such as exemplary computer system **200** shown in Figure 2. Alternatively, the headend server **102** comprises a plurality of computer systems, each like computer system **200**. In an alternate embodiment, the application service **106** and the PSA **108** are implemented using a single computer system, and the ACS **104** is a separate computer system. In another embodiment, the application service **106** is implemented using a single computer system, and the ACS **104** and the PSA **108** are implemented on a separate computer system. Other distributions of the application service **106**, the ACS **104**, and the PSA **108** among computer systems are within the scope and spirit of the present invention.

The computer system **200** includes one or more processors, such as processor **202**. The processor **202** is connected to a communication bus **204**. The computer system **200** also includes a main memory **206**, preferably random access memory (RAM), and a secondary memory **208**. The secondary memory **208** includes, for example, a hard disk drive **210** and/or a removable storage drive **212**, representing a floppy disk drive, a magnetic tape drive, a compact disk drive, etc. The removable storage drive **212** reads from and/or writes to a removable storage unit **214** in a well known manner.

Removable storage unit **214**, also called a program storage device or a computer program product, represents a floppy disk, magnetic tape, compact disk, etc. The removable storage unit **214** includes a computer usable storage medium having stored therein computer software and/or data, such as an object's methods and data.

The computer system **200** can communicate with other computer systems via network interface **215**. The network interface **215** is a network interface circuit card that connects computer system **200** to other computer systems via network **216**. The other computer systems can be computer systems such as

computer system **200**, set-top box audio clients **112**, or PCs and/or workstations. The network **216** can be one of fiber optics, coaxial, or 10BaseT.

Computer programs (also called computer control logic), including object-oriented computer programs, are stored in main memory **206** and/or the secondary memory **208**. Such computer programs, when executed, enable the computer system **200** to perform the features of the present invention as discussed herein. In particular, the computer programs, when executed, enable the processor **202** to perform the features of the present invention. Accordingly, such computer programs represent controllers of the computer system **200**.

In another embodiment, the invention is directed to a computer program product comprising a computer readable medium having control logic (computer software) stored therein. The control logic, when executed by the processor **202**, causes the processor **202** to perform the functions of the invention as described herein.

In yet another embodiment, the invention is implemented primarily in hardware using, for example, one or more state machines. Implementation of these state machines to perform the functions described herein will be apparent to persons skilled in the relevant art(s).

ACS Threads

The ACS **104** is a multi-threaded process having multiple threads, each thread executing a separate audio conference function. The ACS **104** contains a thread for managing audio conferences, a thread for monitoring the system, a thread for keeping track of conference ownership, a thread for receiving audio data from audio clients, and a thread for mixing and delivering audio data.

Figure 3 is a diagram **300** representing the multiple threads of the ACS **104**. Upon initialization, the ACS **104** creates three threads. The first thread

is a conference manager thread **302** that handles incoming IDL method calls from the application service **106**. The second thread is a conference recycler thread **304** that monitors the system and performs appropriate garbage collection. The third thread is a resource audit service (RAS) pinger thread **306** that checks the status of the registered owner of a conference.

Users interactively interface with the ACS **104** via the ACS shell. The ACS shell enables program access to low level IDL methods. The conference manager thread **302** handles all incoming IDL method calls from the application service **106**. The low level IDL methods that are handled by the conference manager thread **302** are discussed below (under ACS Shell).

The ACS **104** needs to know if the application that created an audio conference is still running. When the audio conference is generated and used by the same application, the application reports that it is alive by pinging the ACS **104**. The conference recycler thread **304** monitors the pinging. When the pinging stops, the conference recycler thread **304** terminates the audio conference.

When the audio conference is generated by one application and used by a different application, the above method of pinging the conference recycler thread **304** is not applicable. For example, a game launcher application generates a conference that is used by a game. To accommodate this situation, the RAS pinger thread **306** is used. The RAS pinger thread **306** is responsible for pinging a resource audit service (RAS) to obtain information about the existence of the registered owner of a conference. Conference ownerships are registered with the RAS via a registered owner interface. Using the RAS pinger thread **306**, the RAS informs the ACS **104** when the registered conference owner stops running. The incorporation of the RAS pinger thread **306** enables an application claiming ownership of an audio conference to pass

audio conference ownership to another application using the registered owner interface.

An audio conference ownership transfer will now be discussed with reference to Figures 4, 5A and 5B. Figure 4 is an exemplar process **400** representing a conference ownership transfer using the RAS pinger thread **306**. Two applications are shown in Figure 4. The first application is a box office application **402**. The second application is a theatre application **404**. The box office application **402** sells tickets to viewers. Since no one can enter the theatre without purchasing a ticket from the box office, the box office application **402** creates the audio conference and registers itself as the owner of the conference with the ACS **104**. Once the tickets have all been sold and the attraction is ready to begin, the viewers enter the theatre room. At this time the box office application **402** passes audio conference ownership to the theatre application **404** and registers the theatre application **404** as the owner of the conference with the ACS **104**.

The ACS **104** keeps a lookup table **406** in which each audio conference has a matching entry **408**. The matching entry **408** is the registered owner of the conference. When the theatre application **404** terminates, the ACS **104** detects the termination and closes the conference.

The RAS **410** keeps track of a registered application. The RAS **410** pings the registered application using IDL and also checks for its existence via the operating system. When the registered application ceases to exist, the RAS **410** notifies the ACS **104**. If the application was the registered owner of the conference, then ACS **104** closes the conference and cleans up. In the above example, when the viewers leave the theatre and the theatre application **404** ceases to exist, the RAS **410** reports it to the ACS **104**. The ACS **104** looks at the table, sees that the registered owner is gone, and closes the conference.

Figures 5A and 5B represent a flow diagram **500** of the process of changing a registered owner of a conference. With reference to Figure 5A, in step **502** a first application starts the conference, and control passes to step **504**. In step **504**, the owner of the conference is registered with the ACS **104** (shown as arrow **412** in Figure 4). The ACS **104** enters the owner of the conference in the lookup table **406** in step **506a** (shown as arrow **414** in Figure 4). The ACS **104** then informs the RAS **410** that it is interested in knowing when the first application ceases to exist in step **506b** (shown as arrow **416** in Figure 4). Control then passes to decision step **507**.

In decision step **507**, it is determined whether the first application wants to move the conference. If the first application does not want to move the conference, control stays with decision step **507**. If the first application wants to move the conference, control passes to step **508**.

In step **508**, the first application moves the conference ownership to a second application (shown as arrow **418** in Figure 4). Conference ownership in the second application is then passed to the ACS **104** in step **510** (shown as arrow **420** in Figure 4).

Referring to Figure 5B, in step **512**, the second application is registered as the owner of the conference, and the ACS **104** rewrites the lookup table **406** to reflect the new owner of the conference in step **514a** (shown as arrow **422** in Figure 4). The ACS **104** then informs the RAS **410** that it is interested in knowing when the second application ceases to exist in step **514b** (shown as arrow **424** in Figure 4). Control then passes to decision step **515**.

In decision step **515**, it is determined whether the second application has ceased. If the second application is still running, control remains in step **515**. When the second application ceases, control passes to step **516**.

In step **516**, the RAS **410** reports the loss of the second application to the ACS **104** (shown as arrow **426** in Figure 4). Control then passes to decision step **517**.

In decision step **517**, it is determined whether the second application is registered as the owner of the conference in the lookup table. If the second application is not registered as the owner of the conference in the lookup table, control remains in step **517**. If the second application is registered as the owner of the conference in the lookup table, control passes to step **518**. In step **518**, the ACS **104** closes the conference.

Returning to Figure 3, when a new conference starts, two new threads are generated in the ACS **104**. The first new thread is a net listener thread **308**. The net listener thread **308** receives audio data from audio clients **112** via the network. The second new thread is a mixer thread **310**. The mixer thread **310** performs actual audio mixing and delivers the mixed audio data to the audio clients **112** through the network. Actual audio mixing will be discussed below.

The net listener thread **308** receives upstream audio data packets that are sent from the STB **112**. The net listener thread **308** listens to the network. Whenever STBs **112** send data over the network via UDP/IP **128**, the net listener thread **308** gathers the audio data packets and passes them to the mixer thread **310** via a shared buffer (not shown) located between the net listener thread **308** and the mixer thread **310**.

A PSA can be played from the application service **106** or from within the ACS **104**. Figure 6 is a diagram **600** representing the play back of a PSA **108**. When PSAs **108** are played from the application service **106**, one thread **604**, called thAudioSource, per PSA is generated in the application service **106**. The thAudioSource thread **604** gets audio from the file (i.e., PSA **108**) and sends it to the ACS **104** via UDP/IP. After the application service **106** sends the PSA **108** to the ACS **104**, the process is the same as described for a set-top

audio client **112** (i.e., the data is received by the net listener thread **308** and passed to the mixer thread **310** where it is mixed and sent to the designated audio clients **112** over the network via UDP/IP).

As previously stated, an application can play a PSA **108** in the ACS **104**. When an application plays the PSA **108** in the ACS **104**, the net listener thread **308** directly fetches the audio data from the file (i.e., PSA **108**). This reduces the network traffic of the audio stream.

Audio Mixing and Delivery

As previously stated, the mixer thread **310** performs actual audio mixing and delivers the mixed audio data to the audio clients **112** through the network via UDP/IP **128**. The present invention provides audio mixing with distance-based attenuation. When an audio client (PSAs **108** or STBs **112**) moves closer to another audio client (PSAs **108** or STBs **112**), the sound gets louder, and when the audio client (PSAs **108** or STB **112**) retreats, the sound gets quieter. A PSA **108** might be, for example, the sound of a snoring dragon. When an audio client represented by a STB **112** moves closer to the dragon, the snoring sounds louder, and when the STB **112** retreats, the snoring sound is quieter.

The ACS **104** accomplishes this by implementing decay characteristics for categories of sounds. Figure 7 represents a graph **700** showing pre-defined decay factors for four categories of sounds. Graph **700** plots volume vs. distance for each pre-defined decay factor.

The first pre-defined decay factor represents a sound of constant volume regardless of distance. This plot is identified as audioConstant **702**. AudioConstant sounds are heard at the same volume from anywhere on the TV screen **126**. The second pre-defined decay factor represents a sound of loud volume. This plot is identified as audioBig **704**. AudioBig sounds can be heard by an audio client (PSA **108** or STB **112**) anywhere on the TV screen **126**

(shown on TV screen **706**), and even several screens away. The third pre-defined decay factor represents a sound of low volume. This plot is identified as audioSmall **712**. AudioSmall sounds can only be heard by audio clients (PSAs **108** and STBs **112**) who are near the sound source on the TV screen **126** (shown on TV screen **714**). The small sound (audioSmall **712**) decays to zero inversely and more quickly than the big sound (audioBig **704**). The last pre-defined decay factor represents a medium sound, i.e., a sound that falls between audioBig **704** and audioSmall **712**. This plot is identified as audioMedium **708**. AudioMedium sounds can be heard on approximately half of the TV screen **126**, but not beyond the TV screen **126** (shown on TV screen **710**). Medium sounds decay linearly, in between the small and big sounds. Developers can also customize decay factor values. A plot of an exemplary custom decay factor **716** is also shown in graph **700**.

When audio clients (PSAs **108** and STBs **112**) are added to the conference, the application specifies the decay factor for that audio client (PSA **108** or STB **112**). As previously stated, audio data received from audio clients (STBs **112**) is received via the net listener thread **308**. The mixer thread **310** performs the actual audio mixing and delivers the mixed audio data to the audio clients (STBs **112**) through the network via UDP/IP **128**. The actual audio mixing is accomplished by generating an audio mix table. An exemplary audio mix table **800** is shown in Figure 8. The mix table **800** contains weighted values for each source audio client (STB **112**) in relationship to each target audio client (PSA **108** or STB **112**) in the conference. A target audio client (STB **112**) is the audio client that is receiving the sound. According to graph **700**, the target audio client (STB **112**) always resides at location (0,0). A source audio client (PSA **108** or STB **112**) is the audio client from which the sound is emanating. Weighted values for each source audio client (STB **112**) are extracted from graph **700** according to the distance between the target audio

client (STB **112**) and the source audio client (PSA **108** or STB **112**) using the decay factor specified for the source audio client (PSA **108** or STB **112**) when that source audio client (PSA **108** or set-top box **112**) was added to the conference. The weighted values range from 0.0 to 1.0, with 0.0 indicating no volume and 1.0 indicating maximum volume.

The mix table **800** shows that the weight of a target audio client (STB **112**) to itself is 0.0. Thus the target audio client (STB **112**) will not be able to hear its own echo.

The audio mix to be delivered to target audio client audio1 **802** is 0.0 for audio client audio1 **802**, 1.0 for audio client audio2 **804**, and 0.7 for audio client audio3 **806**. This indicates that audio client audio1 **802** will hear audio client audio2 **804** at maximum volume and audio client audio3 **806** at 70% of the maximum volume. Equation **808** represents the audio mix for target audio client audio1 **802**. Equations **810** and **812** represent the audio mix for target audio clients audio2 **804** and audio3 **806**, respectively.

The mixer thread **310** also refines the mixed audio using the following functions: gain control, fading in/fading out, floating point operation elimination, mixing adaption, mixing cut-off and stream audio. The gain control function controls the gain to avoid transmitting excess energy audio data after calculating the weighted sum. The fading in/fading out function avoids the delivery of audio data in a step-wise manner to the speaker output (which results in discontinuity on the user side) by smoothing the audio data on fading in and fading out. The floating point operation elimination function avoids floating point operation by using pre-calculated weight functions instead of performing actual floating point multiplication. The mixing adaption function is used to adapt an actual mix calculation for a source audio client to the available CPU resources. The mixing cut-off function provides better scalability by allowing a mixing cut-off of three, in which the three nearest

talking audio clients are selected for the actual mix. The stream audio function prepares stream audio for two purposes: (1) playing ambient background music, such as radio in cyber-space; and (2) using it as an audio source forwarded from another conference. An example of refining an audio mix using both the mixing adaption and mixing cut-off functions follows.

After the mixer thread **310** mixes the audio data, the mixed PCM audio data packet is sent over the network via UDP/IP **128** to the corresponding audio clients (STBs **112**). Whether the full active mix for each audio client (STBs **112**) is sent depends on the availability of CPU resources. If the CPU resources are busy, the active mix for any one audio client (STB **112**) will be reduced. For example, if an audio client's active mix is equivalent to:

$$\begin{aligned} audioX = {} & 0.1\times audio1 + 0.3\times audio2 + 0.5\times audio3 + \\ & 0.7\times audio4 + 1.0\times audio5 + 0.0\times audioX, \end{aligned}$$

and adequate CPU resources were available, the entire active mix could be delivered to audioX. Alternatively, if CPU resources were busy, then the active mix would be reduced. The reduction might be to delete audio1 and audio2 since they are only heard by audioX at 10% and 30% of the maximum volume, respectively.

Figure 9A is a flow diagram **900** representing the functionality of the mixer thread **310**. Flow diagram **900** begins by receiving audio data from the net listener thread **308** and from PSAs **108** generated in the application service **106** or the ACS **104** in step **902**. Control then passes to step **904**.

In step **904**, audio mixing is performed for each source audio client in the conference to provide spatialized audio. Control then passes to step **906** where delivery of the actual audio mix to the target audio clients (STBs **112**) is performed.

Figure 9B is a flow diagram **910** representing the audio mixing process **904**. Flow diagram **910** begins by identifying the decay factor for each source audio client in step **912**. Control then passes to step **914**.

In step **914**, the distance between the target audio client and each source audio client is determined. Using the distances determined in step **914**, a weighted value is extracted using the identified decay factors from step **912** for each source audio client in step **916**. Control then passes to step **918**.

In step **918**, the weighted values determined in step **916** are entered into a mix table for each source/target audio client pair. The actual mix values are calculated in step **920** for each target audio client. The resultant audio mix values are refined in step **922**.

ACS Shell

The ACS shell **110**, written in TCL (a tool command language developed by John Ousterhout of the University of California, Berkeley), is an IDL client that connects to the ACS **104** and provides an interactive interface to monitor and control the full range of ACS functions. The ACS shell **110** enables developers to quickly prototype an application and operators to monitor and control audio conferences. The ACS shell **110** provides an ACS shell command prompt for prompting a user to enter ACS shell commands. The ACS shell prompt identifies the shell, time, and history, for example, acsshell <10:09am>[1]%. ACS shell commands enable the user to examine the execution of and interact with audio conferences and audio clients (PSAs **108** and STBs **112**).

ACS shell commands that provide audio conferencing functionality are divided into four distinct classes. Figure 10 is a diagram **1000** representing program access and internal interfaces to the ACS shell audio conferencing classes, as well as the interrelationship among classes. The classes include an

ACProxy class **1002**, a PSA class **1004**, and AudioConference and AudioConferenceService classes **1006**.

The easiest way to use the ACS **104** is through the ACProxy class **1002**. The ACProxy class provides a higher level of functionality than the lower level AudioConference and AudioConferenceService classes **1006**. The ACProxy class **1002** provides most, but not all, of the functionality implemented by the lower level classes **1006**. The ACProxy class **1002** also calculates sound relationships (mixed audio) automatically when audio clients change position.

Methods **1100** contained in the ACProxy class **1002** are shown in Figure 11. The ACProxy methods **1100** enable the creation of a proxy audio conference. There are fourteen (14) methods in the ACProxy class **1002**. The methods include:

(1) ACProxy() method **1102**
(2) ~ACProxy() method **1104**;
(3) AddClient() method **1106**;
(4) AddPSA() method **1108**;
(5) Audios() method **1110**;
(6) DemuteAudio() method **1112**;
(7) GetAudioLocation() method **1114**;
(8) GetConfInfo() method **1116**;
(9) MoveAudio() method **1118**;
(10) MuteAudio() method **1120**;
(11) RegisterOwner() method **1122**;
(12) RegisterOwnerByName() method **1124**;
(13) RemoveAudio() method **1126**; and
(14) UnregisterOwner() method **1128**.

The ACProxy() **1102** and ~ACProxy() **1104** methods allow the opening and closing of a proxy audio conference, respectively. Methods AddClient() **1106** and AddPSA() **1108** add STB **112** and PSA **108** audio clients to the proxy audio conference, respectively. Audio clients (PSAs **108** and STBs **112**) are identified using client IDs. The method Audios() **1110** lists the audio client ID

numbers of all audio clients (PSAs **108** and STBs **112**) in the proxy audio conference. The audio of a PSA **108** is enabled and disabled using methods DemuteAudio() **1112** and MuteAudio() **1120**, respectively.

A proxy audio conference registers ownership of the application to the ACS **104**. The ACS **104** then pings the RAS **410** to see if the application continues to exist. To transfer conference ownership to another application, methods RegisterOwner() **1122** and RegisterOwnerByName() **1124** are invoked. The RegisterOwner() method **1122** transfers ownership of the proxy audio conference using an object reference. The RegisterOwnerByName() method **1124** transfers ownership of the audio conference using the name of the application. The UnregisterOwner() method **1128** removes the previous ownership of the audio conference.

The ACProxy class **1002** allows one to specify a TV screen location for an audio client (PSA **108** or set-top box **112**) and calculates the changes in sound automatically when audio clients (PSAs **108** and STBs **112**) move. This is accomplished by invoking the MoveAudio() method **1118**. The X, Y coordinate location of an audio client (PSA **108** or STB **112**) is displayed when the GetAudioLocation() method **1114** is invoked.

To remove audio clients (PSAs **108** or STBs **112**), the RemoveAudio() method **1126** is invoked. Audio conference information is displayed by invoking the GetConfInfo() method **1116**.

An example of how to add audio clients to a proxy conference by invoking methods from the ACProxy class **1002** is shown in Figure 15. Figure 15 is a flow diagram **1500** representing the addition of an audio client to a proxy audio conference. Flow diagram **1500** begins by adding an audio client to the proxy audio conference in step **1502**. The audio client can be a STB **112** or a PSA **108**. If the audio client is a STB **112**, the AddClient() method **1106** is invoked. If the audio client is a PSA **108**, the AddPSA() method **1108** is

invoked. The audio client ID and the decay factor (**702**, **704**, **708**, **712**, or **716**) must be specified in the parenthetical of the AddClient() method **1106** or the AddPSA() method **1108**. Control then passes to step **1504**.

In step **1504**, the audio client is located onscreen by invoking the MoveAudio() method **1118**. If the audio client is a STB **112**, the character representing the audio client is located onscreen. If the audio client is a PSA **108**, the sound source representation of the audio client is located onscreen. When locating an audio client onscreen, the audio client ID and the X, Y coordinates of the audio client must be specified in the parenthetical. The origin, (0,0), is the lower left corner of the TV screen.

Referring back to Figure 10, the most complete method of using the ACS shell **110** is by accessing the PSA class **1004**, and the AudioConference and AudioConferenceService classes **1006** directly. PSAs **108** are initiated by accessing the PSA class **1004**. As previously stated, PSAs **108** can be files or audio lines.

The PointSourceAudio class methods **1200** are shown in Figure 12. These methods allow the user to instance or delete a point source as well as play, pause, stop, and resume play of a point source. The PointSourceAudio class **1004** contains six (6) methods (**1202-1212**). The six methods include:

(1) PointSourceAudio() method **1202**;
(2) ~PointSourceAudio() method **1204**;
(3) Play() method **1206**;
(4) Stop() method **1208**;
(5) Pause() method **1210**; and
(6) Resume() method **1212**.

The PointSourceAudio() method **1202** instantiates a PSA object. To play the audio source, the Play() method **1206** is invoked. To stop playing the audio source, the Stop() method **1208** is invoked. To resume playing the audio source, the Resume() method **1212** is invoked. The Pause() method **1210**

pauses the playing of the audio source. To clean up resources and close the device used by the PSA **108**, the ~PointSourceAudio() method **1204** is invoked.

Referring back to Figure 10, the audio conference methods provided by the AudioConferenceService and AudioConference classes **1006** are direct IDL calls to the ACS **104**. Thus, the conference manager thread **302** handles these incoming method calls. The ACProxy class **1002** and the PointSourceAudio class **1004** are wrappers to these IDL interfaces.

The AudioConferenceService methods **1300** are shown in Figure 13. The AudioConferenceService class **1006** contains five (5) methods (**1302** - **1310**). The five (5) methods include:

(1) OpenConference() **1302**;
(2) CloseConference() **1304**;
(3) GetConferenceByTicket() **1306**;
(4) ListConference() **1308**; and
(5) HctAudioStat() **1310**.

The OpenConference() **1302** and CloseConference() **1304** methods create and close an audio conference. An audio conference is identified by a ticket number. To locate a conference name by ticket number, the GetConferenceByTicket() method **1306** is invoked. One can also obtain a listing of the online conferences by invoking the ListConference() method **1308**. Information about STB **112** audio clients can be obtained by invoking the HctAudioStat() method **1310**. The data provided for STB **112** audio clients includes such information as:

(1) the host IP address of the ACS **104**;
(2) the UDP port on the ACS server that handles the UDP/IP audio data packets;
(3) the port on the set-top side that handles the UDP/IP audio data packets;
(4) the ID of the set-top where this audioID is mapped to;
(5) the number that identifies each audio conference;
(6) the date and time that the audio client (**112**) was created;

(7) the most recent access of the client or ping;
(8) the most recent time that the ACS **104** received audio data from this audio client (**112**); and
(9) the most recent time that the ACS **104** sent audio data to this audio client (**112**).

The methods for the AudioConference class **1400** are shown in Figure 14. There are sixteen methods in the AudioConference class **1006**. They include:

(1) NewAudio() **1402**;
(2) DeleteAudio() **1404**;
(3) RegisterOwner() **1406**;
(4) RegisterOwnerByName() **1408**;
(5) UnregisterOwner() **1410**;
(6) SetMixOne() **1412**;
(7) SetMix() **1414**;
(8) GetMixOne() **1416**;
(9) GetMix() **1418**;
(10) SetTimeOut() **1420**;
(11) GetTimeOut() **1422**;
(12) AudioIds() **1424**;
(13) AudioStat() **1426**;
(14) ConfStat() **1428**;
(15) HctAudioStat() **1430**; and
(16) Ping() **1432**.

The methods in the AudioConferenceService and AudioConference class **1300** and **1400,** respectively, provide greater control over the audio conference than the ACProxy class methods **1100**. As one can see from the lists of methods, one can open and close audio conferences, create and delete audio clients, set an automatic timeout, and set the volume levels between clients.

The RegisterOwner() method **1406**, the RegisterOwnerByName() method **1408**, and the UnregisterOwner() method **1410** are similar to the ACProxy methods **1122**, **1124**, and **1128**. For descriptions of these methods

(**1406**, **1408**, and **1410**) refer to the discussion of the ACProxy methods (**1122**, **1124**, and **1128**) given above.

Methods NewAudio() **1402** and DeleteAudio() **1404** create an audio client for a given STB **112** and delete an audio client, respectively. The methods SetMixOne() **1412** and GetMixOne() **1416** set the volume and return the volume setting of the conversations between two audio clients (PSAs **108** and STBs **112**), respectively. The SetMix() method **1414** and the GetMix() method **1418** set the volume and return the volume setting between many audio client pairs. The SetTimeOut() method **1420** sets a number of seconds of inactivity, after which the conference is closed automatically. A conference can be set to never close, if desired. The GetTimeOut() method **1422** finds the length in seconds of the timeout. The Ping() method **1432** pings a given audio conference and returns an exception if the conference does not exist.

The remaining methods (**1424-1430**) all deal with providing information about the conference. The AudioIds() method **1424** returns a list of audio IDs in a conference. The AudioStat() method **1426** returns information about an audio client, given the audio ID. The ConfStat() method **1428** returns information about an audio conference, and the HctAudioStat() method **1430** returns information about an audio client, given the STB ID.

Figure 16 is an exemplary flow diagram **1600** representing an audio conference in a service application using the lower level methods of the AudioConferenceService and AudioConference class **1300** and **1400**. The procedural steps in flow diagram **1600** are presented as a guide. Other procedural step distributions for a service application using these lower level methods are within the scope and spirit of the present invention.

Flow diagram **1600** begins in step **1602**. In step **1602** an audio conference in an application is opened by invoking the OpenConference()

method **1302**. The ticket number identifying the audio conference or audio conference ID is returned. Control then passes to step **1604**.

In step **1604**, a set-top box audio client **112** is added to the conference by invoking the NewAudio() method **1402**. The NewAudio() method **1402** returns an audio ID representative of the set-top box **112**. Additional audio clients can be created by invoking the NewAudio() method **1402** or the PointSourceAudio() method **1202**. Control then passes to step **1606**.

In step **1606**, the volume between audio clients is set by invoking the SetMixOne() method **1412**. The audio ID of both the receiver and the sender, as well as the mix (i.e., the weighted factor) must be included in the parenthetical of the SetMixOne() method **1412**. If one needed to set up the relative volumes between many viewers, the SetMix() method **1414** would be invoked. The SetMix() method **1414** combines multiple IDL calls into one call. Control then passes to step **1608**.

In step **1608**, the audio client is removed by invoking the DeleteAudio() method **1404**. To delete an audio client, the audio ID of the audio client to be deleted must be specified in the parenthetical of the DeleteAudio() method **1404**. Control then passes to step **1610**, where the audio conference in the application is closed by invoking the CloseConference() method **1304**.

Conclusion

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What Is Claimed Is:

1. An audio conference server (ACS) for enabling an application program to provide multi-point, weight controllable audio conferencing, comprising:

means for managing at least one audio conference, said at least one audio conference comprising a plurality of audio clients;

means for receiving audio data from said plurality of audio clients;

means for mixing said audio data to provide spatialized audio to said plurality of audio clients in said at least one audio conference, wherein said mixing means results in mixed audio data; and

means for delivering said mixed audio data to said plurality of audio clients in said at least one audio conference.

2. The ACS of claim 1, wherein said mixing means includes means for providing distance-based attenuation according to sound decay characteristics.

3. The ACS of claim 1, further comprising means for checking the status of a registered owner of said at least one audio conference to determine whether said at least one audio conference still exists.

4. The ACS of claim 3, wherein said checking means includes a resource audit service, said resource audit service operable when said at least one audio conference is generated by a first application and is being used by a second application.

5. The ACS of claim 1, wherein said plurality of audio clients includes set-top box (STB) audio clients and point source audio (PSA) audio clients.

6. The ACS of claim 1, wherein said managing means comprises an ACS shell to allow a user to interactively interface with said ACS, said ACS shell including:

means for providing program access to high level methods for creating and managing a proxy audio conference;

means for providing program access to methods for creating and managing a plurality of PSA audio clients; and

means for providing program access to low level methods for creating and managing said at least one audio conference.

7. The ACS of claim 2, wherein said means for providing distance-based attenuation according to sound decay characteristics comprises:

means for identifying a decay factor from one of a plurality of pre-defined decay factors and a customized decay factor for each of said plurality of audio clients, said plurality of pre-defined decay factors including

an audio big decay factor,

an audio small decay factor,

an audio medium decay factor, and

a constant decay factor;

means for determining distances between a target audio client and a plurality of source audio clients;

means for determining a plurality of weighted values for each of said source audio clients based on said identified decay factor and said distance between each of said source audio clients and said target audio client, wherein each of said weighted values corresponds to a source/target audio client pair;

means for generating a mix table for each of said source/target audio client pairs;

means for calculating an actual mix for said target audio clients; and

means for refining said actual mix for said target audio clients.

8. The ACS of claim 7, wherein said refining means comprises:

a gain control function to avoid transmitting excess energy audio data;

a fade in/fade out function to avoid the delivery of said audio data in a step-wise manner to a speaker output;

a floating point operation elimination function to avoid the performance of floating point multiplication;

a mixing adaption function to adapt the actual mix calculation for said target audio client to available CPU resources;

a mixing cut-off function to select the nearest talking audio clients for the actual mix; and

a stream audio function to prepare stream audio for playing ambient background music or using an audio source forwarded from another conference.

9. A method for enabling an audio conference server to provide an application program with multi-point, weight controllable audio conferencing, comprising the steps of:

(1) managing at least one audio conference, said at least one audio conference comprising a plurality of audio clients;

(2) receiving audio data from said plurality of audio clients;

(3) mixing said audio data to provide spatialized audio to said plurality of audio clients in said at least one audio conference, wherein said mixing means results in mixed audio data; and

(4) delivering said mixed audio data to said plurality of audio clients in said at least one audio conference.

10. The method of claim 9, wherein said mixing step includes providing distance-based attenuation according to sound decay characteristics.

11. The method of claim 9, further comprising the step of checking the status of a registered owner of said at least one audio conference to determine whether said at least one audio conference still exists.

12. The method of claim 11, wherein said checking step includes a resource audit service, said resource audit service operable when said at least one audio conference is generated by a first application and is being used by a second application.

13. The method of claim 9, wherein said plurality of audio clients includes set-top box (STB) audio clients and point source audio (PSA) audio clients.

14. The method of claim 9, wherein step (1) comprises the step of providing program access to high level methods for creating and managing a proxy audio conference using an ACS shell.

15. The method of claim 9, wherein step (1) comprises the step of providing program access to methods for creating and managing said point source audio using an ACS shell.

16. The method of claim 9, wherein step (1) comprises the step of providing program access to low level methods for creating and managing said at least one audio conference using an ACS shell.

17. The method of claim 10, wherein said step for providing distance-based attenuation according to sound decay characteristics comprises the steps of:

identifying a decay factor from one of a plurality of pre-defined decay factors and a customized decay factor for each of said plurality of audio clients, said plurality of pre-defined decay factors including

an audio big decay factor,

an audio small decay factor,

an audio medium decay factor, and

a constant decay factor;

determining distances between a target audio client and a plurality of source audio clients;

determining a plurality of weighted values for each of said source audio clients based on said identified decay factor and said distance between each of said source audio client and said target audio client, wherein each of said weighted values corresponds to a source/target audio client pair;

generating a mix table for each of said source/target audio client pairs;

calculating an actual mix for said target audio clients using said mix table; and

refining said actual mix for said target audio clients, wherein said refining step is used to avoid transmitting excess energy audio data, avoid the delivery of said audio data in a step-wise manner to a speaker output, avoid the performance of floating point multiplication, adapt the actual mix calculation for said target audio client to available CPU resources, select the nearest talking audio clients for the actual mix, and prepare stream audio for playing ambient background music or using an audio source forwarded from another conference.

18. A computer program product comprising a computer useable medium having computer program logic recorded thereon for enabling an audio conference server (ACS) to provide an application program with multi-point, weight controllable audio conferencing, said computer program logic comprising:

means for enabling the computer to manage at least one audio conference, said at least one audio conference comprising a plurality of audio clients;

means for enabling the computer to receive audio data from said plurality of audio clients;

means for enabling the computer to mix said audio data to provide spatialized audio to said plurality of audio clients in said at least one audio conferences, wherein said mixing means results in mixed audio data; and

means for enabling the computer to deliver said mixed audio data to said plurality of audio clients in said at least one audio conference.

19. The computer program product of claim 18, wherein said means for enabling the computer to mix said audio data to provide spatialized audio to said plurality of audio clients in said at least one audio conference includes means for enabling the computer to provide distance-based attenuation according to sound decay characteristics.

20. The computer program product of claim 18, further comprising means for enabling the computer to check the status of a registered owner of said at least one audio conference to determine whether said at least one audio conference still exists.

21. The computer program product of claim 20, wherein said means for enabling the computer to check the status of a registered owner of said at least one audio conference includes a resource audit service, said resource audit service operable when said at least one audio conference is generated by a first application is being used by a second application.

22. The computer program product of claim 18, wherein said plurality of audio clients includes set-top box (STB) audio clients and point source audio (PSA) audio clients.

23. The computer program product of claim 18, wherein said means for enabling the computer to manage at least one audio conference comprises means for enabling the computer to provide an ACS shell to allow a user to interactively interface with said ACS, said ACS shell including:

means for enabling the computer to provide program access to high level methods for creating and managing a proxy audio conference;

means for enabling the computer to provide program access to methods for creating and managing a plurality of point source audio (PSA) audio clients; and

means for enabling the computer to provide program access to low level methods for creating and managing said at least one audio conference.

24. The computer program product of claim 19, wherein said means for enabling the computer to provide distance-based attenuation according to sound decay characteristics comprises:

means for enabling the computer to identify a decay factor from one of a plurality of pre-defined decay factors and a customized decay factor for each

of said plurality of audio clients, said plurality of pre-defined decay factors including

an audio big decay factor,

an audio small decay factor,

an audio medium decay factor, and

a constant decay factor;

means for enabling the computer to determine distances between a target audio client and a plurality of source audio clients;

means for enabling the computer to determine a plurality of weighted values for each of said source audio clients based on said identified decay factor and said distance between said source audio client and said target audio client, wherein each of said weighted values corresponds to a source/target audio client pair;

means for enabling the computer to generate a mix table for each of said source/target audio client pairs;

means for enabling the computer to calculate an actual mix for said source audio clients; and

means for enabling the computer to refine said actual mix for said source audio clients.

25. The computer program product of claim 24, wherein said means for enabling the computer to refine said actual mix for said source audio clients comprises:

means for enabling the computer to provide a gain control function to avoid transmitting excess energy audio data;

means for enabling the computer to provide a fade in/fade out function to avoid the delivery of said audio data in a step-wise manner to a speaker output;

means for enabling the computer to provide a floating point operation elimination function to avoid the performance of floating point multiplication;

means for enabling the computer to provide a mixing adaption function to adapt the actual mix calculation for said target audio client to available CPU resources;

means for enabling the computer to provide a mixing cut-off function to select the nearest talking audio clients for the actual mix; and

means for enabling the computer to provide a stream audio function to prepare stream audio for playing ambient background music or using an audio source forwarded from another conference.

Spatialized Audio in a Three-Dimensional, Computer-Based Scene

Abstract

A system and method for enabling an audio conference server (ACS) to provide an application program with multi-point weight controllable audio conferencing. The ACS manages a plurality of audio conferences, receives audio data from a plurality of audio clients, mixes the audio data to provide distance-based attenuation according to decay characteristics for each sound, and delivers the mixed audio data to a plurality of audio clients. Audio clients include set-top box (STB) audio clients and point source audio (PSA) audio clients. The ACS mixes the audio data by identifying a decay factor. Pre-defined decay factors include an audio big decay factor, an audio small decay factor, an audio medium decay factor, and a constant decay factor. One can also develop a customized decay factor. A weighted value for a source audio client based on the identified decay factor and the distance between the source audio client and a target audio client is determined. A mix table is generated using the weighted values for each source/target audio client pair. Then an actual mix value for each target audio client is calculated using the mix table. The present invention also includes means for refining the actual mix value.

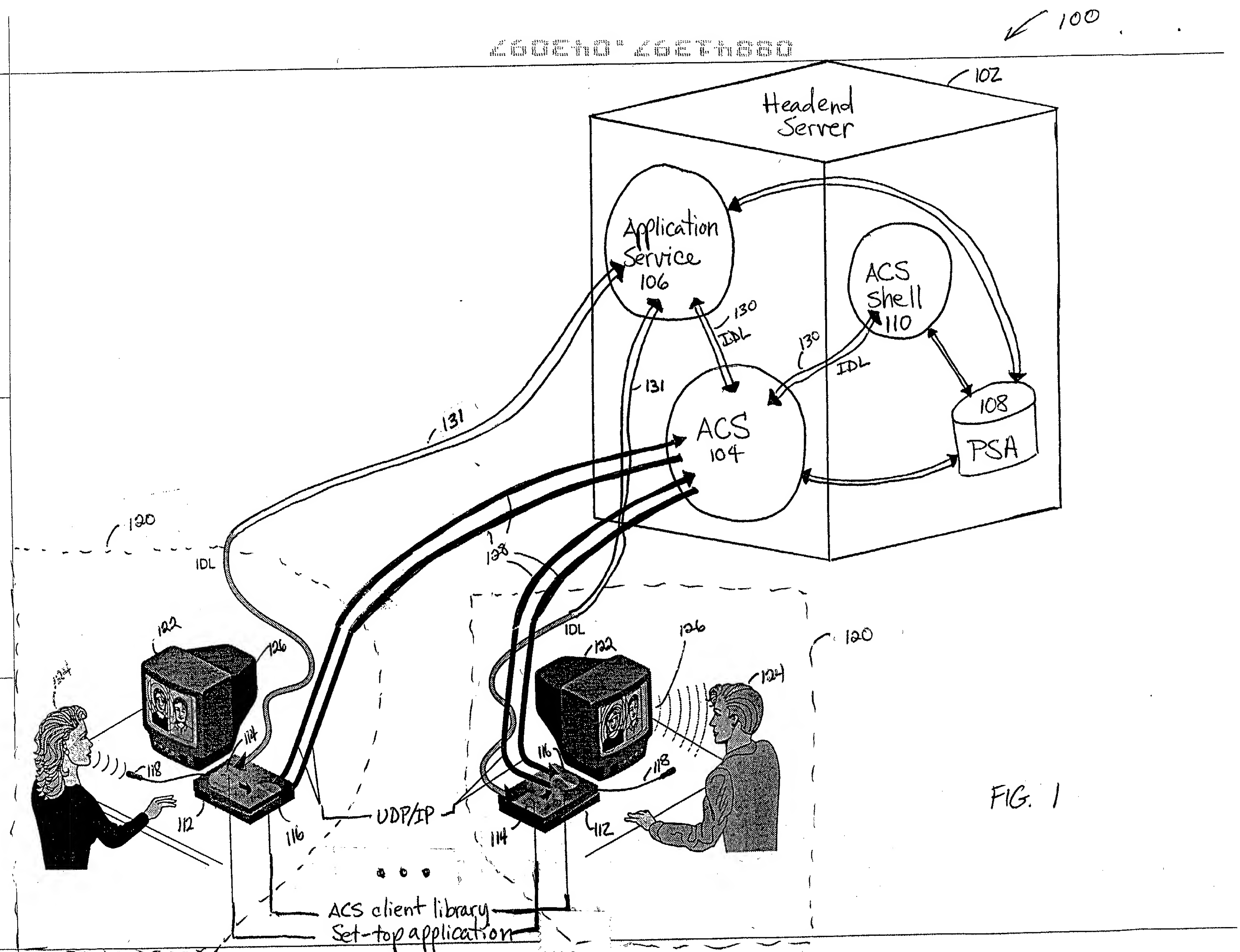
100
102
Headend Server
Application Service 106
ACS Shell 110
ACS 104
108 PSA
130
IDL
131
128
120
122
124
126
118
114
116
112
UDP/IP
ACS client library
Set-top application

FIG. 1

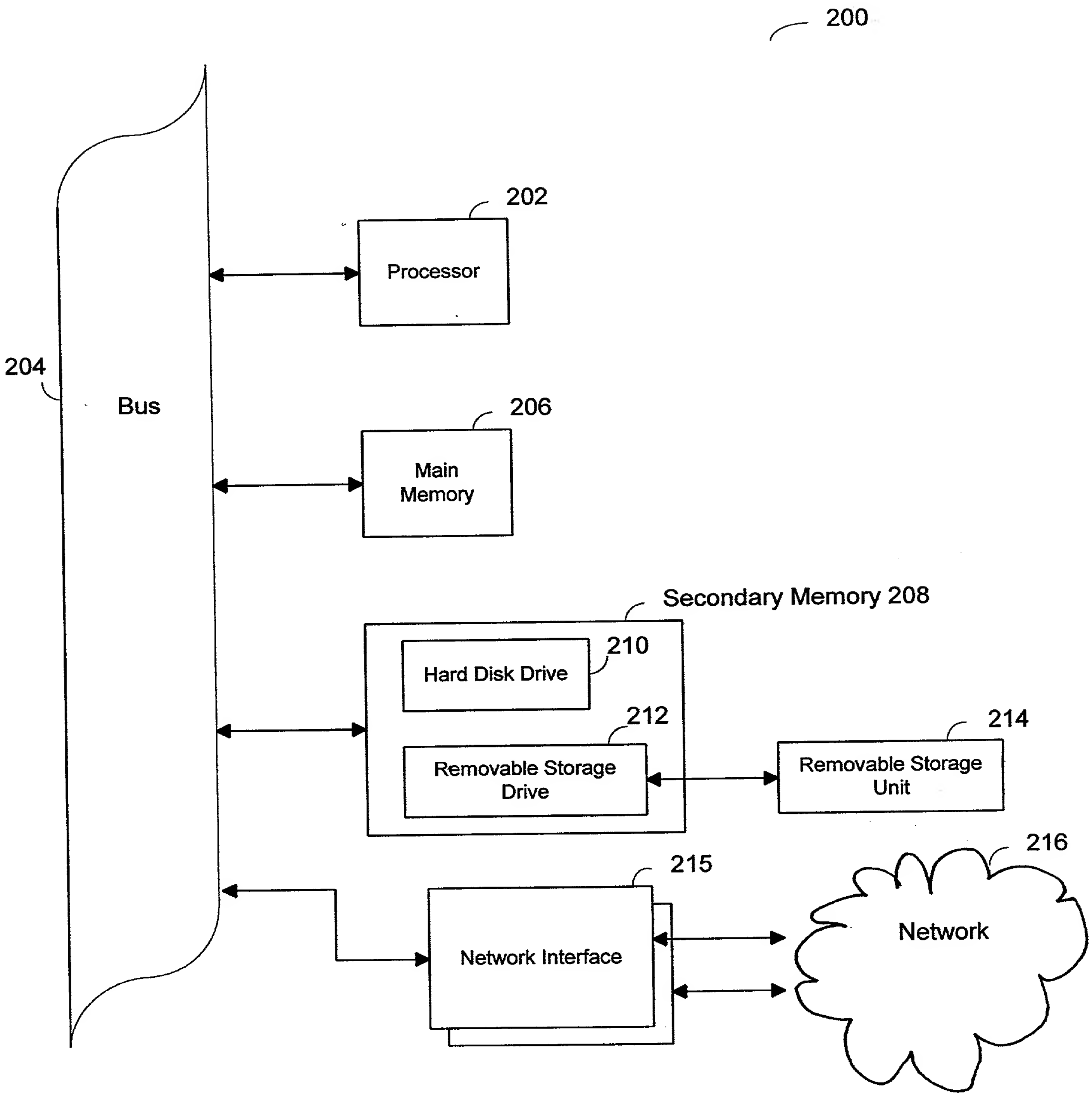
200
Bus
204
202
Processor
206
Main Memory
Secondary Memory 208
Hard Disk Drive
210
212
Removable Storage Drive
214
Removable Storage Unit
215
Network Interface
216
Network

FIG. 2

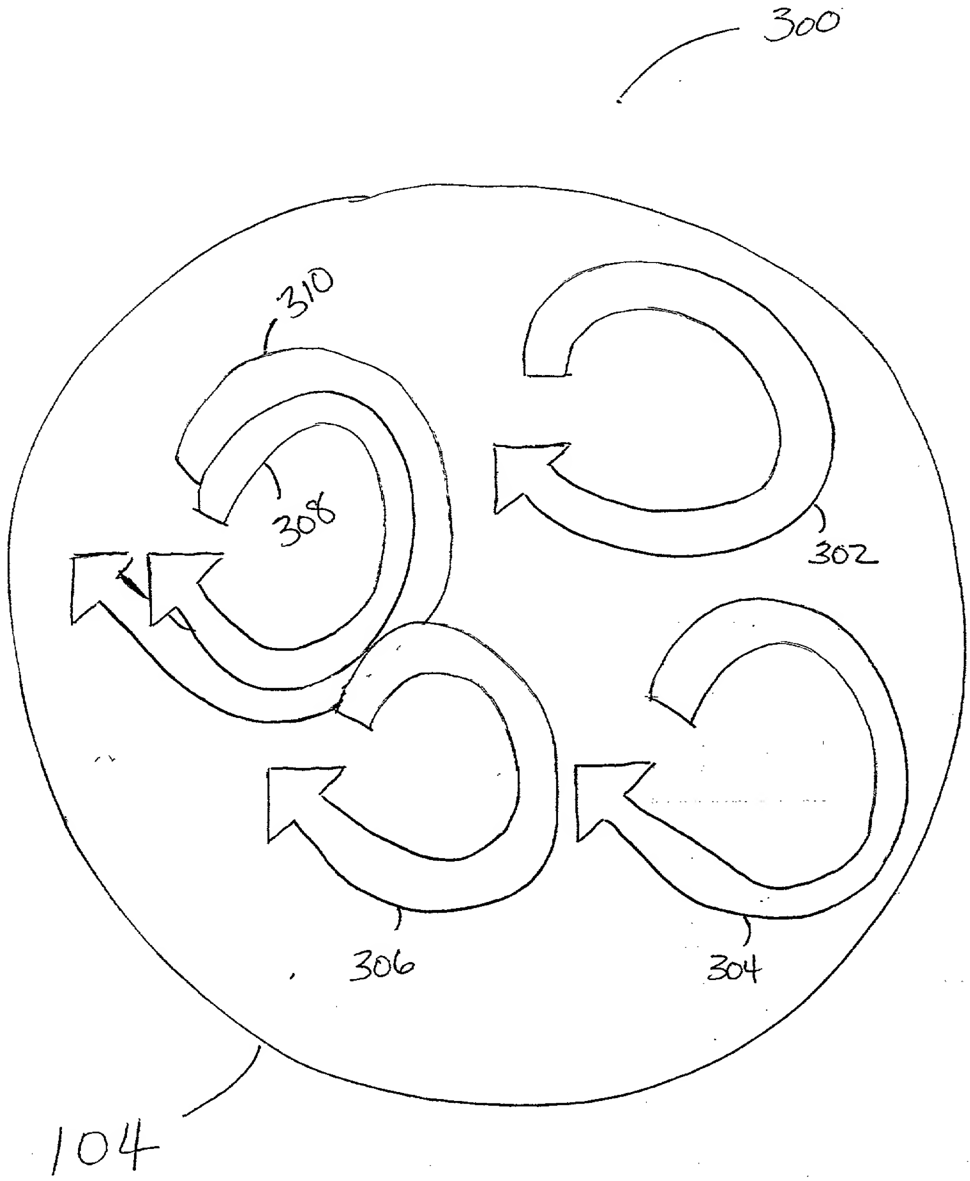

FIG. 3

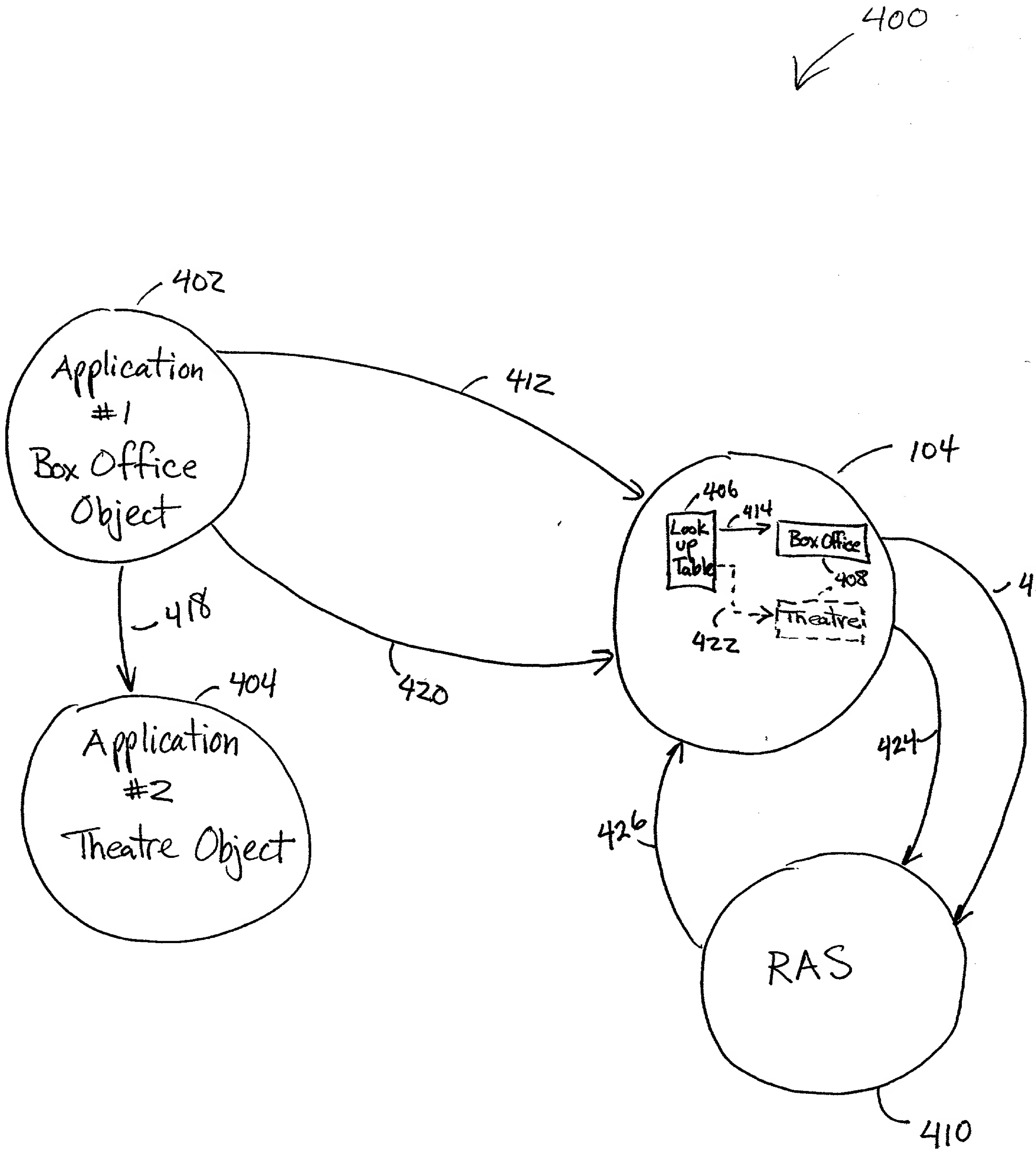
400
402
Application
#1
Box Office
Object
412
104
406
414
Look
up
Table
Box Office
408
Theatre
422
416
418
420
404
Application
#2
Theatre Object
424
426
RAS
410

FIG4

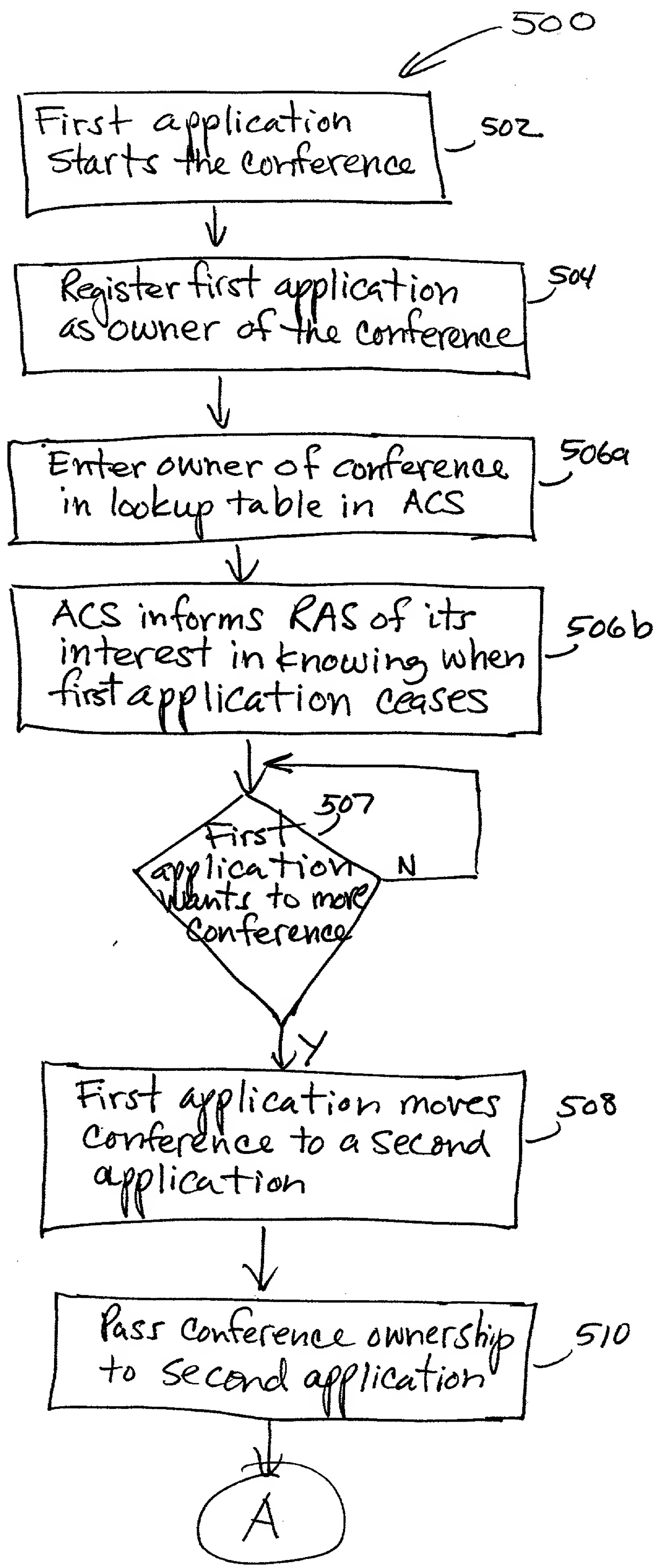
500
First application starts the conference
502
Register first application as owner of the conference
504
Enter owner of conference in lookup table in ACS
506a
ACS informs RAS of its interest in knowing when first application ceases
506b
First application wants to move conference
507
N
Y
First application moves conference to a second application
508
Pass conference ownership to second application
510
A

FIG. 5A

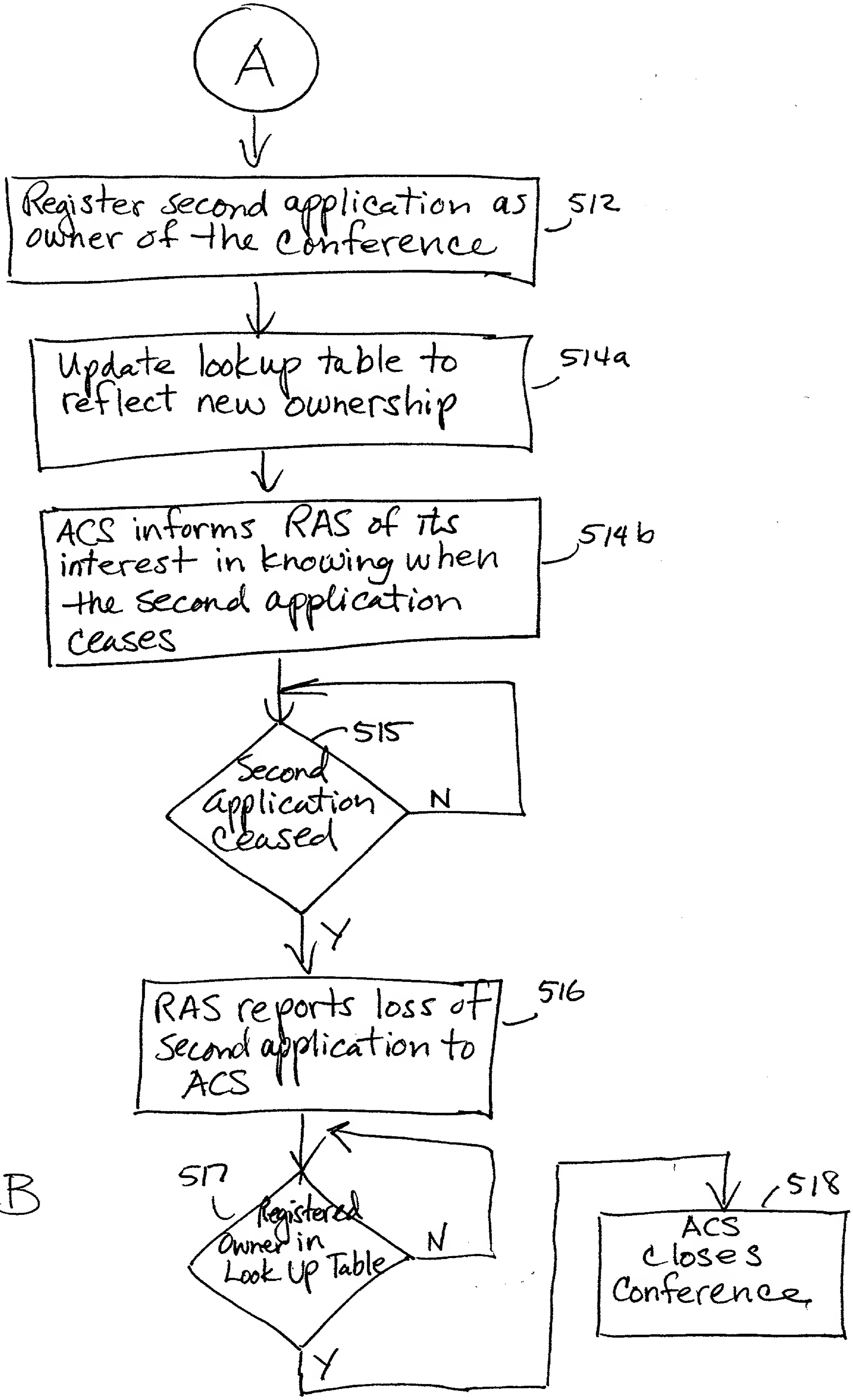
A
Register second application as owner of the conference
512
Update lookup table to reflect new ownership
514a
ACS informs RAS of its interest in knowing when the second application ceases
514b
Second application ceased
515
N
Y
RAS reports loss of second application to ACS
516
Registered Owner in Look Up Table
517
N
Y
ACS closes Conference
518

FIG. 5B

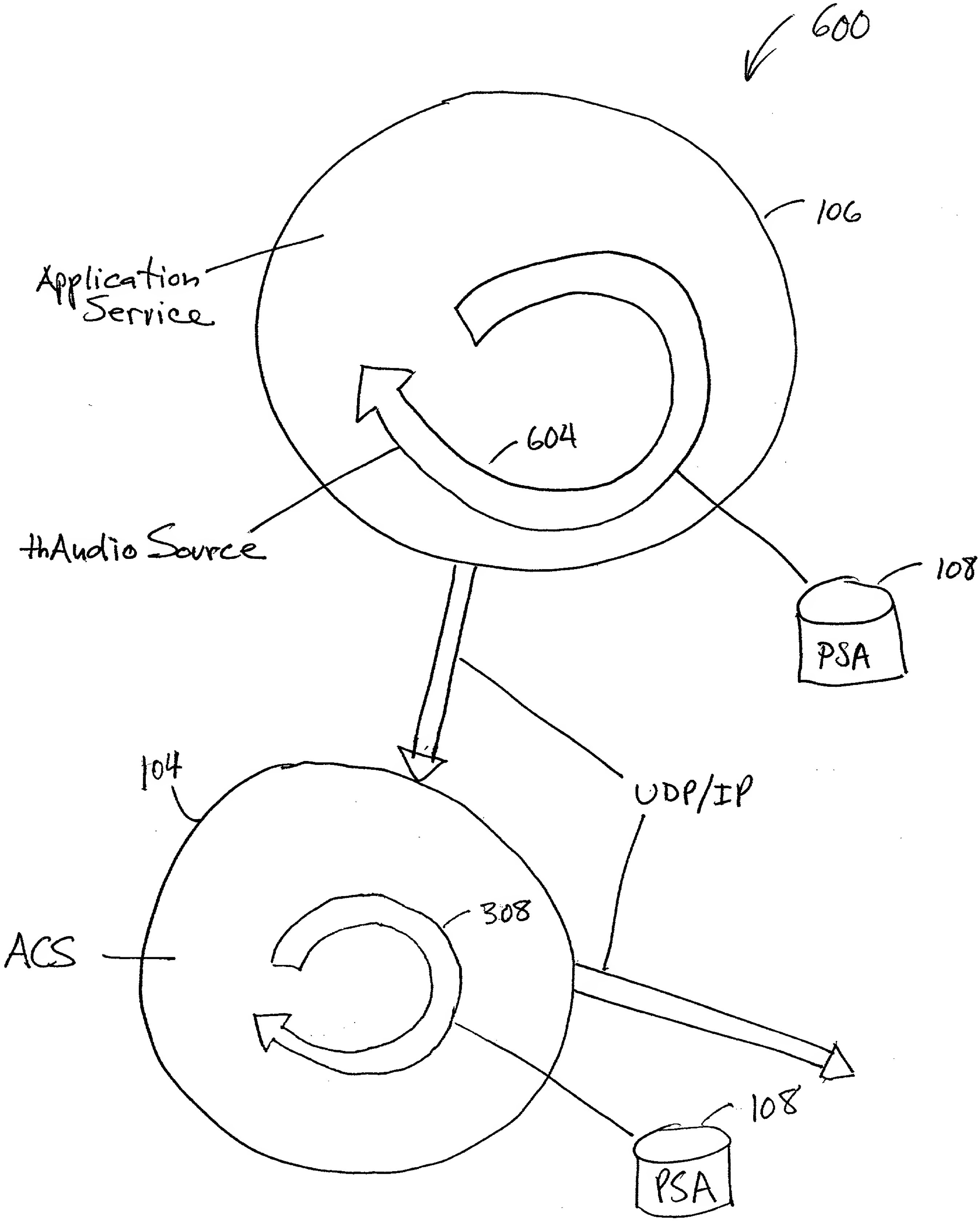
600
106
Application Service
604
thAudio Source
108
PSA
104
UDP/IP
308
ACS
108
PSA

FIG. 6

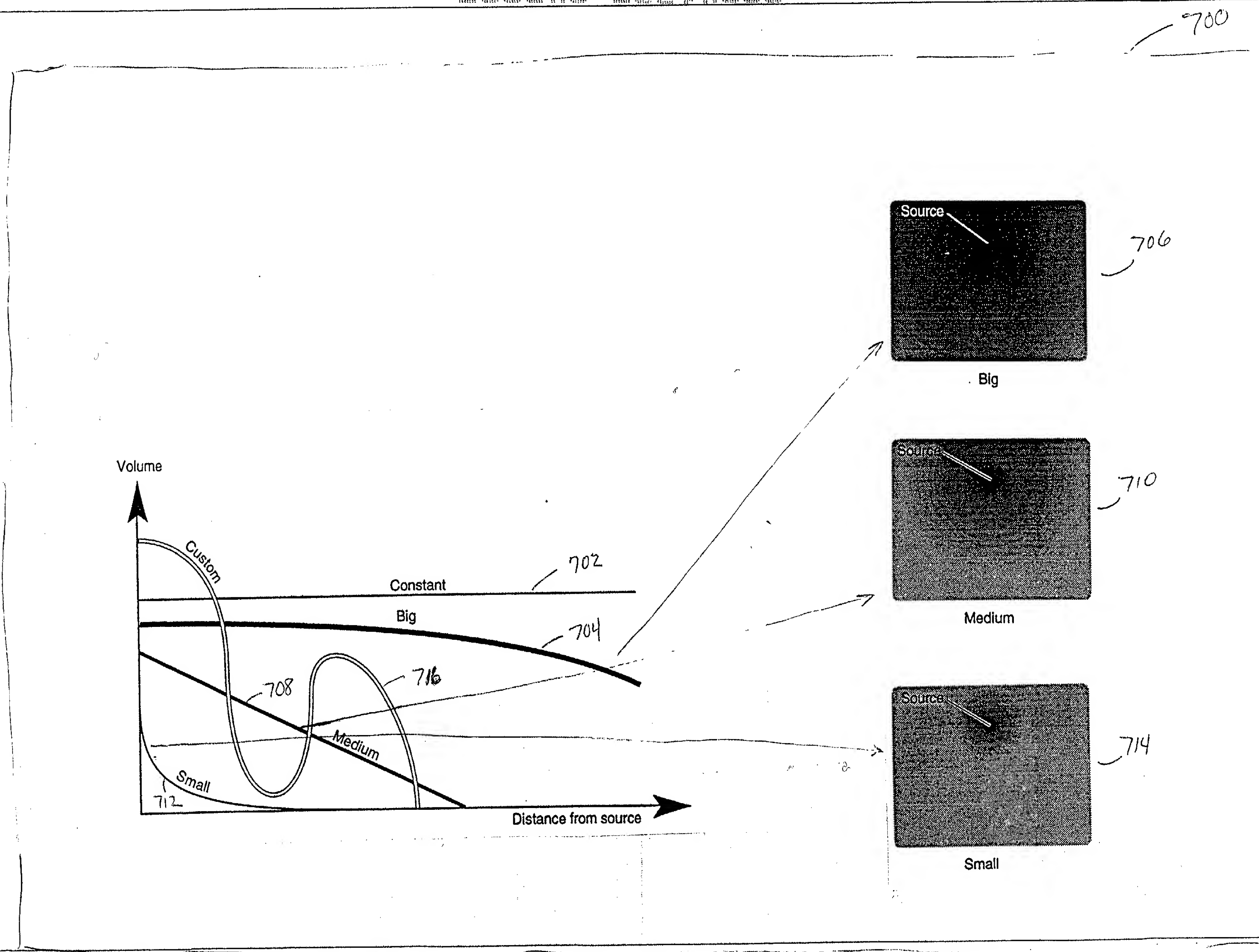
700
Volume
Custom
Constant
702
Big
704
708
716
Medium
Small
712
Distance from source
Source
Big
706
Source
Medium
710
Source
Small
714

FIG. 7

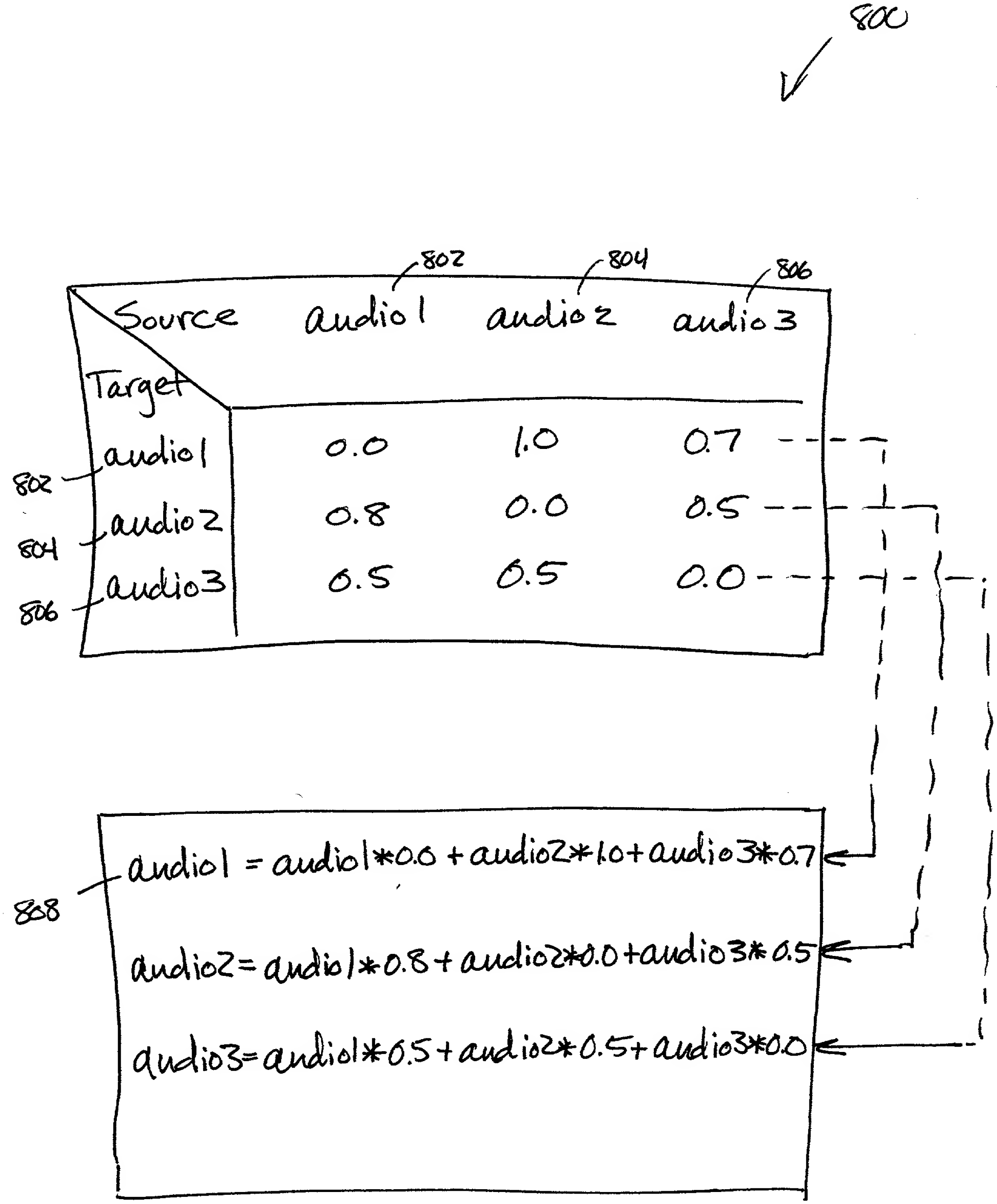
800
802
804
806
Source
Target
audio1
audio2
audio3
0.0
1.0
0.7
0.8
0.0
0.5
0.5
0.5
0.0
808
audio1 = audio1*0.0 + audio2*1.0 + audio3*0.7
audio2 = audio1*0.8 + audio2*0.0 + audio3*0.5
audio3 = audio1*0.5 + audio2*0.5 + audio3*0.0

FIG. 8

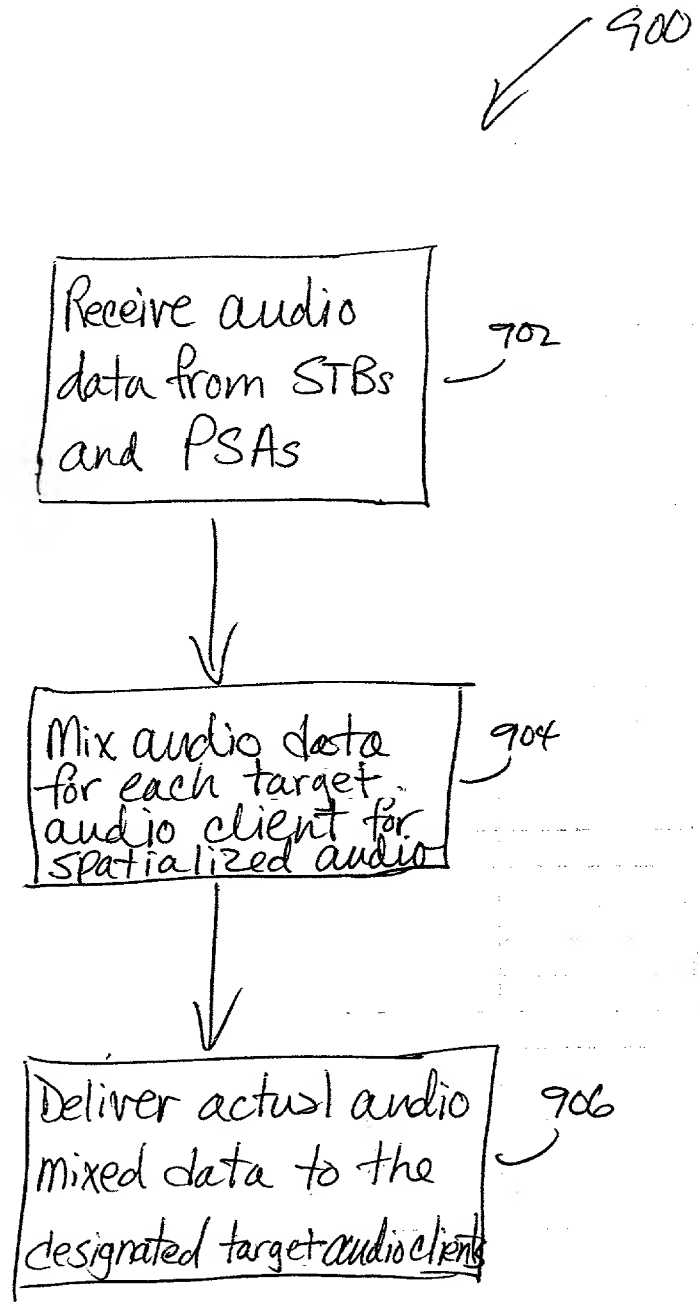
900
Receive audio data from STBs and PSAs
902
Mix audio data for each target audio client for spatialized audio
904
Deliver actual audio mixed data to the designated target audio clients
906

FIG. 9A

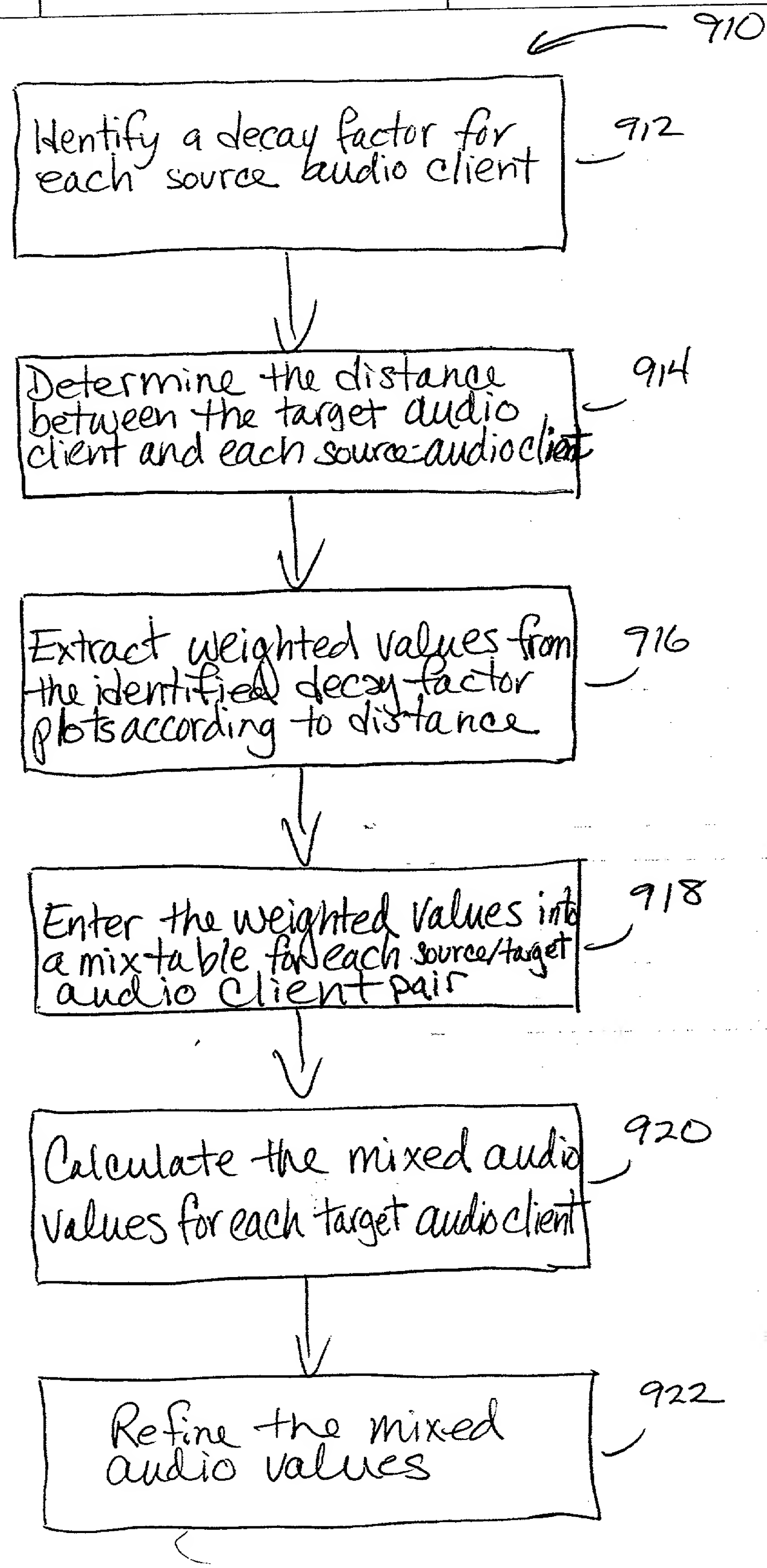
910
Identify a decay factor for each source audio client
912
Determine the distance between the target audio client and each source audio client
914
Extract weighted values from the identified decay factor plots according to distance
916
Enter the weighted values into a mix table for each source/target audio client pair
918
Calculate the mixed audio values for each target audio client
920
Refine the mixed audio values
922

FIG. 9B

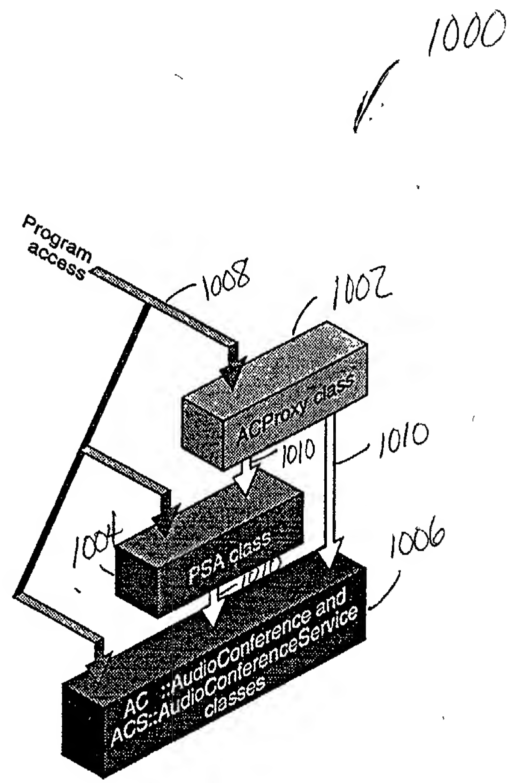
1000
Program access
1008
1002
ACProxy class
1010
1010
1004
PSA class
1006
AC ::AudioConference and
ACS::AudioConferenceService
classes

Fig. 10

ACProxy Class Methods ~ 1100

	Method	Description
1102	ACProxy()	Opens the audio conference.
1104	~ACProxy()	Cleans up and closes the audio conference.
1106	AddClient()	Adds set-top audio client to the audio conference.
1108	AddPSA()	Adds a PSA audio client to the conference.
1110	Audios()	Lists audio client IDs in the conference.
1112	DemuteAudio()	Enables audio of the PSA.
1114	GetAudioLocation()	Locates X,Y coordinates of an audio client.
1116	GetConfInfo()	Retrieves audio conference information.
1118	MoveAudio()	Moves audio source to a specified location.
1120	MuteAudio()	Disables audio of the PSA.
1122	RegisterOwner()	Transfer owner of the audio conference using the object reference.
1124	RegisterOwnerByName()	Transfer owner of the audio conference using the name of the application as exported by the Name Space.
1126	RemoveAudio()	Removes the audio client.
1128	UnregisterOwner()	Removes previous ownership of the audio conference.

Fig. 11

PointSourceAudio Class Methods ~ 1200

	Method	Description
1202~	PointSourceAudio()	Class constructor. Instantiates a PSA object.
1204~	~PointSourceAudio()	Cleans up resources, closes the device used by a PSA.
1206~	Play()	Plays the audio source.
1208~	Stop()	Stops playing the audio source.
1210~	Pause()	Pauses the playing of the audio source.
1212~	Resume()	Resumes playing the audio source.

Fig. 12

1300

The **ACS::AudioConferenceService** methods

1302 • **OpenConference()** — creates an audio conference.

1304 • **CloseConference()** — closes an audio conference.

1306 • **GetConferenceByTicket()** — finds the conference name given the ticket number.

1308 • **ListConference()** — returns a sequence of conference objects.

1310 • **HctAudioStat()** — finds information about a set-top audio client.

Fig. 13

1400

The **ACS::AudioConference** methods

- 1402 **NewAudio()** — creates an audio client for a given set-top box.
- 1404 **DeleteAudio()** — deletes an audio client.
- 1406 **RegisterOwner()** — registers conference owner by object reference
- 1408 **RegisterOwnerByName()** — registers conference owner by export name
- 1410 **UnregisterOwner()** — removes a registered conference ownership
- 1412 **SetMixOne()** — sets the volume of the conversation between two audio clients.
- 1414 **SetMix()** — sets the volume of the conversations between many audio client pairs.
- 1416 **GetMixOne()** — returns the volume setting between two audio client pairs.
- 1418 **GetMix()** — returns the volume settings between many audio client pairs.
- 1420 **SetTimeOut()** — sets a number of seconds of inactivity, after which the conference is closed automatically. It can be set to never close.
- 1422 **GetTimeOut()** — finds the length in seconds of the timeout.
- 1424 **AudioIds()** — gets a list of audio IDs in a conference.
- 1426 **AudioStat()** — gets information about an audio client given the audio ID.
- 1428 **ConfStat()** — gets information about an audio conference.
- 1430 **HctAudioStat()** — gets information about an audio client given the set-top ID.
- 1432 **Ping()** — pings a given audio conference and returns an exception if the conference doesn't exist.

FIG. 14

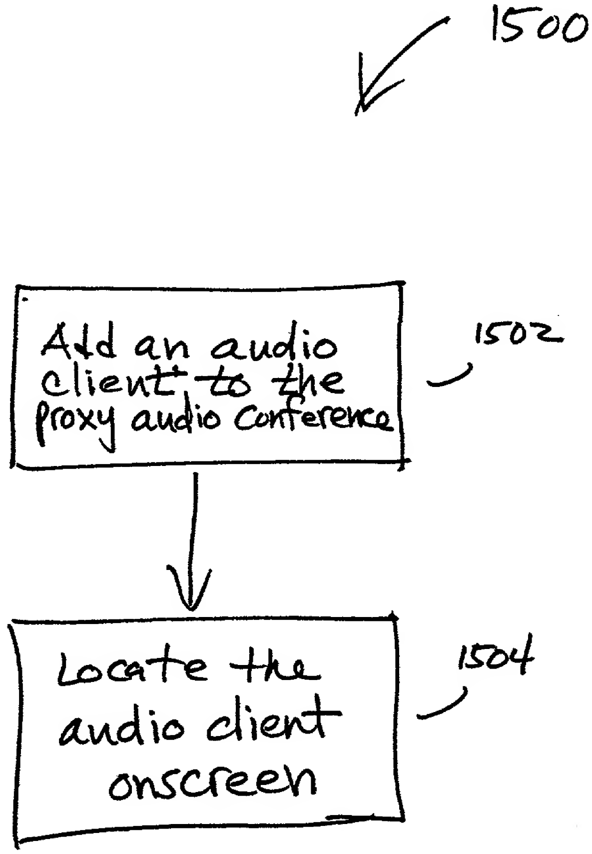
1500
Add an audio client to the proxy audio conference
1502
Locate the audio client onscreen
1504

FIG. 15

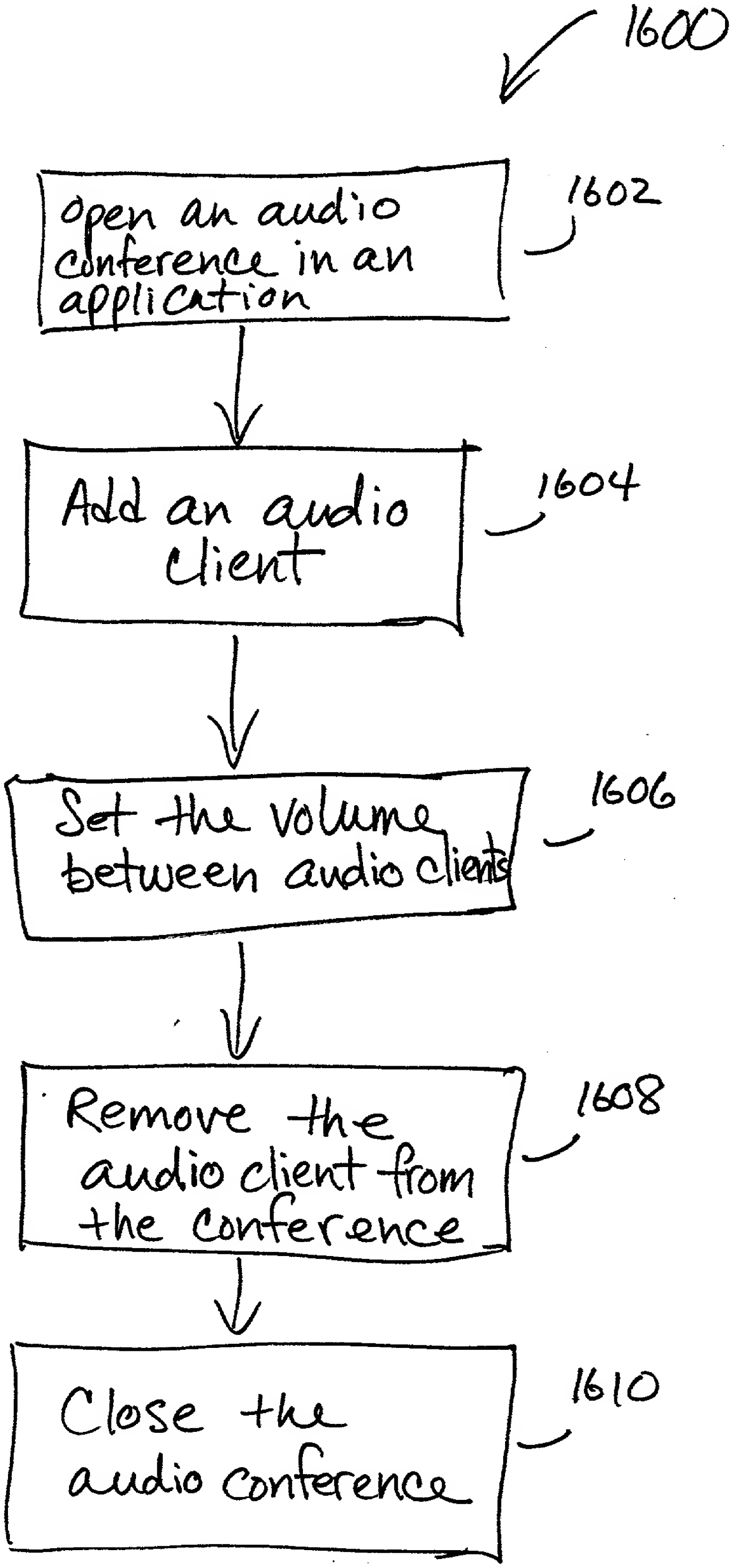
1600
open an audio conference in an application
1602
Add an audio client
1604
Set the volume between audio clients
1606
Remove the audio client from the conference
1608
Close the audio conference
1610

FIG. 16

Combined Declaration and Power of Attorney for Patent Application

Docket Number: 15-4-499.00

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled
Spatialized Audio in a Three-Dimensional, Computer-Based Scene, the specification of which is attached hereto unless the following box is checked:

☐ was filed on ______________;
as United States Application Number or PCT International Application Number __________; and
was amended on ______________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information that is material to patentability as defined in 37 C.F.R. § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)			Priority Claimed
(Application No.)	(Country)	(Day/Month/Year Filed)	☐ Yes ☐ No
(Application No.)	(Country)	(Day/Month/Year Filed)	☐ Yes ☐ No

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below.

(Application No.)	(Filing Date)
(Application No.)	(Filing Date)

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information that is material to patentability as defined in 37 C.F.R. § 1.56 that became available between the filing date of the prior application and the national or PCT International filing date of this application.

(Application No.)	(Filing Date)	(Status - patented, pending, abandoned)
(Application No.)	(Filing Date)	(Status - patented, pending, abandoned)

Appl. No. (to be assigned)
Docket No. 15-4-499.00

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Christopher Byrne, Esq., Reg. No. 32,204; Irene Hu Fernandez, Esq., Reg. No. 34,625; Steven S. Weiner, Reg. No. 38,330;

Robert G. Sterne, Esq., Reg. No. 28,912; Edward J. Kessler, Esq., Reg. No. 25,688; Jorge A. Goldstein, Esq., Reg. No. 29,021; Samuel L. Fox, Esq., Reg. No. 30,353; David K.S. Cornwell, Esq., Reg. No. 31,944; Robert W. Esmond, Esq., Reg. No. 32,893; Tracy-Gene G. Durkin, Esq., Reg. No. 32,831; Michele A. Cimbala, Esq., Reg. No. 33,851; Michael B. Ray, Esq., Reg. No. 33,997; Robert E. Sokohl, Esq., Reg. No. 36,013; Eric K. Steffe, Esq., Reg. No. 36,688; Andrea G. Reister, Esq., Reg. No. 36,253; and Daniel N. Yannuzzi, Esq., Reg. No. 36,727.

Send Correspondence to:

STERNE, KESSLER, GOLDSTEIN & FOX P.L.L.C.
1100 New York Avenue, N.W., #600
Washington, D.C. 20005-3934

Direct Telephone Calls to:

STERNE, KESSLER, GOLDSTEIN & FOX P.L.L.C. (202) 371-2600

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor: Shinya Matsuoka	
First inventor's signature	Date April-30-1997
Residence: 1885 California Street, #6, Mountain View, California 94041-1732	
Citizenship: Japan	
Post Office Address: 1885 California Street, #6, Mountain View, California 94041-1732	

(Supply similar information and signature for subsequent joint inventors, if any)